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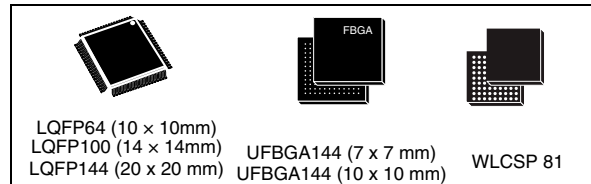


ARM<sup>®</sup> Cortex<sup>®</sup>-M4 32b MCU+FPU, 225DMIPS, up to 512kB Flash/128+4KB RAM,  
USB OTG HS/FS, 17 TIMs, 3 ADCs, 20 comm. interfaces

Datasheet - production data

## Features

- Core: ARM<sup>®</sup> 32-bit Cortex<sup>®</sup>-M4 CPU with FPU, Adaptive real-time accelerator (ART Accelerator™) allowing 0-wait state execution from Flash memory, frequency up to 180 MHz, MPU, 225 DMIPS/1.25 DMIPS/MHz (Dhrystone 2.1), and DSP instructions
- Memories
  - 512 kB of Flash memory
  - 128 KB of SRAM
  - Flexible external memory controller with up to 16-bit data bus: SRAM,PSRAM,SDRAM/LPSDR SDRAM, Flash NOR/NAND memories
  - Dual mode Quad SPI interface
- LCD parallel interface, 8080/6800 modes
- Clock, reset and supply management
  - 1.7 V to 3.6 V application supply and I/Os
  - POR, PDR, PVD and BOR
  - 4-to-26 MHz crystal oscillator
  - Internal 16 MHz factory-trimmed RC (1% accuracy)
  - 32 kHz oscillator for RTC with calibration
  - Internal 32 kHz RC with calibration
- Low power
  - Sleep, Stop and Standby modes
  - V<sub>BAT</sub> supply for RTC, 20×32 bit backup registers + optional 4 KB backup SRAM
- 3×12-bit, 2.4 MSPS ADC: up to 24 channels and 7.2 MSPS in triple interleaved mode
- 2×12-bit D/A converters
- General-purpose DMA: 16-stream DMA controller with FIFOs and burst support
- Up to 17 timers: 2x watchdog, 1x SysTick timer and up to twelve 16-bit and two 32-bit timers up to 180 MHz, each with up to 4 IC/OC/PWM or pulse counter
- Debug mode
  - SWD & JTAG interfaces
  - Cortex<sup>®</sup>-M4 Trace Macrocell™



- Up to 114 I/O ports with interrupt capability
  - Up to 111 fast I/Os up to 90 MHz
  - Up to 112 5 V-tolerant I/Os
- Up to 20 communication interfaces
  - SPDIF-Rx
  - Up to 4 × I<sup>2</sup>C interfaces (SMBus/PMBus)
  - Up to 4 USARTs/2 UARTs (11.25 Mbit/s, ISO7816 interface, LIN, IrDA, modem control)
  - Up to 4 SPIs (45 Mbits/s), 3 with muxed I<sup>2</sup>S for audio class accuracy via internal audio PLL or external clock
  - 2 × SAI (serial audio interface)
  - 2 × CAN (2.0B Active)
  - SDIO interface
  - Consumer electronics control (CEC) I/F
- Advanced connectivity
  - USB 2.0 full-speed device/host/OTG controller with on-chip PHY
  - USB 2.0 high-speed/full-speed device/host/OTG controller with dedicated DMA, on-chip full-speed PHY and ULPI
  - Dedicated USB power rail enabling on-chip PHYs operation throughout the entire MCU power supply range
- 8- to 14-bit parallel camera interface up to 54 Mbytes/s
- CRC calculation unit
- RTC: subsecond accuracy, hardware calendar
- 96-bit unique ID

**Table 1. Device summary**

Reference	Part number
STM32F446xC/E	STM32F446MC, STM32F446ME, STM32F446RC, STM32F446RE, STM32F446VC, STM32F446VE, STM32F446ZC, STM32F446ZE.

# Contents

<b>1</b>	<b>Introduction</b> .....	<b>11</b>
<b>2</b>	<b>Description</b> .....	<b>12</b>
2.1	Compatibility with STM32F4 family .....	14
<b>3</b>	<b>Functional overview</b> .....	<b>17</b>
3.1	ARM® Cortex®-M4 with FPU and embedded Flash and SRAM .....	17
3.2	Adaptive real-time memory accelerator (ART Accelerator™) .....	17
3.3	Memory protection unit .....	17
3.4	Embedded Flash memory .....	18
3.5	CRC (cyclic redundancy check) calculation unit .....	18
3.6	Embedded SRAM .....	18
3.7	Multi-AHB bus matrix .....	18
3.8	DMA controller (DMA) .....	19
3.9	Flexible memory controller (FMC) .....	20
3.10	Quad SPI memory interface (QUADSPI) .....	20
3.11	Nested vectored interrupt controller (NVIC) .....	21
3.12	External interrupt/event controller (EXTI) .....	21
3.13	Clocks and startup .....	21
3.14	Boot modes .....	22
3.15	Power supply schemes .....	22
3.16	Power supply supervisor .....	23
3.16.1	Internal reset ON .....	23
3.16.2	Internal reset OFF .....	23
3.17	Voltage regulator .....	24
3.17.1	Regulator ON .....	24
3.17.2	Regulator OFF .....	25
3.17.3	Regulator ON/OFF and internal reset ON/OFF availability .....	27
3.18	Real-time clock (RTC), backup SRAM and backup registers .....	28
3.19	Low-power modes .....	29
3.20	V <sub>BAT</sub> operation .....	29
3.21	Timers and watchdogs .....	31

3.21.1	Advanced-control timers (TIM1, TIM8)	32
3.21.2	General-purpose timers (TIMx)	32
3.21.3	Basic timers TIM6 and TIM7	32
3.21.4	Independent watchdog	33
3.21.5	Window watchdog	33
3.21.6	SysTick timer	33
3.22	Inter-integrated circuit interface (I <sup>2</sup> C)	33
3.23	Universal synchronous/asynchronous receiver transmitters (USART)	34
3.24	Serial peripheral interface (SPI)	34
3.25	HDMI (high-definition multimedia interface) consumer electronics control (CEC)	35
3.26	Inter-integrated sound (I <sup>2</sup> S)	35
3.27	SPDIF-RX Receiver Interface (SPDIFRX)	35
3.28	Serial Audio interface (SAI)	36
3.29	Audio PLL (PLLI2S)	36
3.30	Serial Audio Interface PLL(PLLSAI)	36
3.31	Secure digital input/output interface (SDIO)	36
3.32	Controller area network (bxCAN)	37
3.33	Universal serial bus on-the-go full-speed (OTG_FS)	37
3.34	Universal serial bus on-the-go high-speed (OTG_HS)	37
3.35	Digital camera interface (DCMI)	38
3.36	General-purpose input/outputs (GPIOs)	38
3.37	Analog-to-digital converters (ADCs)	38
3.38	Temperature sensor	39
3.39	Digital-to-analog converter (DAC)	39
3.40	Serial wire JTAG debug port (SWJ-DP)	39
3.41	Embedded Trace Macrocell™	40
<b>4</b>	<b>Pinout and pin description</b>	<b>41</b>
<b>5</b>	<b>Memory mapping</b>	<b>67</b>
<b>6</b>	<b>Electrical characteristics</b>	<b>72</b>
6.1	Parameter conditions	72
6.1.1	Minimum and maximum values	72

6.1.2	Typical values	72
6.1.3	Typical curves	72
6.1.4	Loading capacitor	72
6.1.5	Pin input voltage	72
6.1.6	Power supply scheme	73
6.1.7	Current consumption measurement	74
6.2	Absolute maximum ratings	74
6.3	Operating conditions	76
6.3.1	General operating conditions	76
6.3.2	VCAP_1/VCAP_2 external capacitor	78
6.3.3	Operating conditions at power-up / power-down (regulator ON)	79
6.3.4	Operating conditions at power-up / power-down (regulator OFF)	79
6.3.5	Reset and power control block characteristics	80
6.3.6	Over-drive switching characteristics	81
6.3.7	Supply current characteristics	81
6.3.8	Wakeup time from low-power modes	101
6.3.9	External clock source characteristics	102
6.3.10	Internal clock source characteristics	107
6.3.11	PLL characteristics	108
6.3.12	PLL spread spectrum clock generation (SSCG) characteristics	110
6.3.13	Memory characteristics	112
6.3.14	EMC characteristics	114
6.3.15	Absolute maximum ratings (electrical sensitivity)	116
6.3.16	I/O current injection characteristics	117
6.3.17	I/O port characteristics	118
6.3.18	NRST pin characteristics	123
6.3.19	TIM timer characteristics	124
6.3.20	Communications interfaces	124
6.3.21	12-bit ADC characteristics	141
6.3.22	Temperature sensor characteristics	147
6.3.23	V <sub>BAT</sub> monitoring characteristics	148
6.3.24	Reference voltage	148
6.3.25	DAC electrical characteristics	148
6.3.26	FMC characteristics	152
6.3.27	Camera interface (DCMI) timing specifications	172
6.3.28	SD/SDIO MMC card host interface (SDIO) characteristics	173
6.3.29	RTC characteristics	175

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<b>7</b>	<b>Package information</b> .....	<b>176</b>
7.1	LQFP64 package information .....	176
7.2	LQFP100 package information .....	179
7.3	LQFP144 package information .....	182
7.4	UFBGA144 7 x 7 mm package information .....	186
7.5	UFBGA144 10 x 10 mm package information .....	189
7.6	WLCSP81 package information .....	192
7.7	Thermal characteristics .....	195
<b>8</b>	<b>Part numbering</b> .....	<b>196</b>
<b>Appendix A</b>	<b>Application block diagrams</b> .....	<b>197</b>
A.1	USB OTG full speed (FS) interface solutions .....	197
A.2	USB OTG high speed (HS) interface solutions .....	199
	<b>Revision history</b> .....	<b>200</b>

## List of figures

Figure 1.	Compatible board design for LQFP100 package	14
Figure 2.	Compatible board for LQFP64 package	15
Figure 3.	STM32F446xC/E block diagram	16
Figure 4.	STM32F446xC/E and Multi-AHB matrix	19
Figure 5.	VDDUSB connected to an external independent power supply	23
Figure 6.	Power supply supervisor interconnection with internal reset OFF	24
Figure 7.	Regulator OFF	26
Figure 8.	Startup in regulator OFF: slow $V_{DD}$ slope power-down reset risen after $V_{CAP\_1}/V_{CAP\_2}$ stabilization	27
Figure 9.	Startup in regulator OFF mode: fast $V_{DD}$ slope power-down reset risen before $V_{CAP\_1}/V_{CAP\_2}$ stabilization.	27
Figure 10.	STM32F446xC/xE LQFP64 pinout	41
Figure 11.	STM32F446xC/xE LQFP100 pinout	42
Figure 12.	STM32F446xC LQFP144 pinout	43
Figure 13.	STM32F446xC/xE WLCSP81 ballout	44
Figure 14.	STM32F446xC/xE UFBGA144 ballout	45
Figure 15.	Memory map	67
Figure 16.	Pin loading conditions	72
Figure 17.	Pin input voltage	72
Figure 18.	Power supply scheme	73
Figure 19.	Current consumption measurement scheme	74
Figure 20.	External capacitor $C_{EXT}$	79
Figure 21.	Typical $V_{BAT}$ current consumption (RTC ON/backup RAM OFF and LSE in low power mode)	91
Figure 22.	Typical $V_{BAT}$ current consumption (RTC ON/backup RAM OFF and LSE in high drive mode)	92
Figure 23.	High-speed external clock source AC timing diagram	104
Figure 24.	Low-speed external clock source AC timing diagram	104
Figure 25.	Typical application with an 8 MHz crystal	105
Figure 26.	Typical application with a 32.768 kHz crystal	106
Figure 27.	$LACC_{HSI}$ versus temperature	107
Figure 28.	$ACC_{LSI}$ versus temperature	108
Figure 29.	PLL output clock waveforms in center spread mode	112
Figure 30.	PLL output clock waveforms in down spread mode	112
Figure 31.	FT I/O input characteristics	120
Figure 32.	I/O AC characteristics definition	123
Figure 33.	Recommended NRST pin protection	124
Figure 34.	I <sup>2</sup> C bus AC waveforms and measurement circuit	126
Figure 35.	FMPI <sup>2</sup> C timing diagram and measurement circuit	128
Figure 36.	SPI timing diagram - slave mode and CPHA = 0	130
Figure 37.	SPI timing diagram - slave mode and CPHA = 1	131
Figure 38.	SPI timing diagram - master mode	131
Figure 39.	I <sup>2</sup> S slave timing diagram (Philips protocol) <sup>(1)</sup>	135
Figure 40.	I <sup>2</sup> S master timing diagram (Philips protocol) <sup>(1)</sup>	135
Figure 41.	SAI master timing waveforms	137
Figure 42.	SAI slave timing waveforms	137
Figure 43.	USB OTG full speed timings: definition of data signal rise and fall time	138
Figure 44.	ULPI timing diagram	140

Figure 45.	ADC accuracy characteristics . . . . .	144
Figure 46.	Typical connection diagram using the ADC . . . . .	145
Figure 47.	Power supply and reference decoupling ( $V_{REF+}$ not connected to $V_{DDA}$ ) . . . . .	146
Figure 48.	Power supply and reference decoupling ( $V_{REF+}$ connected to $V_{DDA}$ ) . . . . .	147
Figure 49.	12-bit buffered/non-buffered DAC . . . . .	151
Figure 50.	Asynchronous non-multiplexed SRAM/PSRAM/NOR read waveforms . . . . .	153
Figure 51.	Asynchronous non-multiplexed SRAM/PSRAM/NOR write waveforms . . . . .	155
Figure 52.	Asynchronous multiplexed PSRAM/NOR read waveforms . . . . .	156
Figure 53.	Asynchronous multiplexed PSRAM/NOR write waveforms . . . . .	158
Figure 54.	Synchronous multiplexed NOR/PSRAM read timings . . . . .	160
Figure 55.	Synchronous multiplexed PSRAM write timings . . . . .	162
Figure 56.	Synchronous non-multiplexed NOR/PSRAM read timings . . . . .	164
Figure 57.	Synchronous non-multiplexed PSRAM write timings . . . . .	165
Figure 58.	NAND controller waveforms for read access . . . . .	167
Figure 59.	NAND controller waveforms for write access . . . . .	167
Figure 60.	NAND controller waveforms for common memory read access . . . . .	168
Figure 61.	NAND controller waveforms for common memory write access . . . . .	168
Figure 62.	SDRAM read access waveforms (CL = 1) . . . . .	169
Figure 63.	SDRAM write access waveforms . . . . .	171
Figure 64.	DCMI timing diagram . . . . .	173
Figure 65.	SDIO high-speed mode . . . . .	173
Figure 66.	SD default mode . . . . .	174
Figure 67.	LQFP64-10x10 mm 64 pin low-profile quad flat package outline . . . . .	176
Figure 68.	LQFP64 Recommended footprint . . . . .	177
Figure 69.	LQFP64 marking example (package top view) . . . . .	178
Figure 70.	LQFP100, 14 x 14 mm 100-pin low-profile quad flat package outline . . . . .	179
Figure 71.	LQFP100 - 100-pin, 14 x 14 mm low-profile quad flat recommended footprint . . . . .	180
Figure 72.	LQFP100 marking example (package top view) . . . . .	181
Figure 73.	LQFP144, 20 x 20 mm, 144-pin low-profile quad flat package outline . . . . .	182
Figure 74.	LQFP144 recommended footprint . . . . .	184
Figure 75.	LQFP144 marking example (package top view) . . . . .	185
Figure 76.	UFBGA144 - 144-pin, 7 x 7 mm, 0.50 mm pitch, ultra fine pitch ball grid array package outline . . . . .	186
Figure 77.	UFBGA144 - 144-ball, 7 x 7 mm, 0.50 mm pitch, ultra fine pitch ball grid array package recommended footprint . . . . .	187
Figure 78.	UQFP144 7 x 7 mm marking example (package top view) . . . . .	188
Figure 79.	UFBGA144 - 144-pin, 10 x 10 mm, 0.80 mm pitch, ultra fine pitch ball grid array package outline . . . . .	189
Figure 80.	UFBGA144 - 144-pin, 10 x 10 mm, 0.80 mm pitch, ultra fine pitch ball grid array package recommended footprint . . . . .	190
Figure 81.	UQFP144 10 x 10 mm marking example (package top view) . . . . .	191
Figure 82.	WLCSP81 - 81-pin, 3.693 x 3.815 mm, 0.4 mm pitch wafer level chip scale package outline . . . . .	192
Figure 83.	WLCSP81- 81-pin, 4.4084 x 3.7594 mm, 0.4 mm pitch wafer level chip scale package recommended footprint . . . . .	193
Figure 84.	WLCSP81 10 x 10 mm marking example (package top view) . . . . .	194
Figure 85.	USB controller configured as peripheral-only and used in Full speed mode . . . . .	197
Figure 86.	USB controller configured as host-only and used in full speed mode . . . . .	197
Figure 87.	USB controller configured in dual mode and used in full speed mode . . . . .	198
Figure 88.	USB controller configured as peripheral, host, or dual-mode and used in high speed mode . . . . .	199



## List of tables

Table 1.	Device summary . . . . .	1
Table 2.	STM32F446xC/E features and peripheral counts. . . . .	13
Table 3.	Voltage regulator configuration mode versus device operating mode . . . . .	25
Table 4.	Regulator ON/OFF and internal reset ON/OFF availability. . . . .	27
Table 5.	Voltage regulator modes in stop mode . . . . .	29
Table 6.	Timer feature comparison. . . . .	31
Table 7.	Comparison of I2C analog and digital filters. . . . .	33
Table 8.	USART feature comparison . . . . .	34
Table 9.	Legend/abbreviations used in the pinout table . . . . .	46
Table 10.	STM32F446xx pin and ball descriptions . . . . .	46
Table 11.	Alternate function . . . . .	59
Table 12.	STM32F446xC/E register boundary addresses . . . . .	68
Table 13.	Voltage characteristics . . . . .	74
Table 14.	Current characteristics . . . . .	75
Table 15.	Thermal characteristics. . . . .	75
Table 16.	General operating conditions . . . . .	76
Table 17.	Limitations depending on the operating power supply range . . . . .	78
Table 18.	VCAP_1/VCAP_2 operating conditions . . . . .	79
Table 19.	Operating conditions at power-up/power-down (regulator ON) . . . . .	79
Table 20.	Operating conditions at power-up / power-down (regulator OFF). . . . .	79
Table 21.	reset and power control block characteristics . . . . .	80
Table 22.	Over-drive switching characteristics . . . . .	81
Table 23.	Typical and maximum current consumption in Run mode, code with data processing running from Flash memory (ART accelerator enabled except prefetch) or RAM. . . . .	83
Table 24.	Typical and maximum current consumption in Run mode, code with data processing running from Flash memory (ART accelerator enabled with prefetch) or RAM. . . . .	84
Table 25.	Typical and maximum current consumption in Run mode, code with data processing running from Flash memory (ART accelerator disabled) . . . . .	85
Table 26.	Typical and maximum current consumption in Sleep mode . . . . .	86
Table 27.	Typical and maximum current consumptions in Stop mode . . . . .	89
Table 28.	Typical and maximum current consumptions in Standby mode . . . . .	90
Table 29.	Typical and maximum current consumptions in V <sub>BAT</sub> mode. . . . .	91
Table 30.	Typical current consumption in Run mode, code with data processing running from Flash memory or RAM, regulator ON (ART accelerator enabled except prefetch), VDD=1.7 V . . . . .	93
Table 31.	Typical current consumption in Run mode, code with data processing running from Flash memory, regulator OFF (ART accelerator enabled except prefetch). . . . .	94
Table 32.	Typical current consumption in Sleep mode, regulator ON, VDD=1.7 V . . . . .	95
Table 33.	Typical current consumption in Sleep mode, regulator OFF. . . . .	96
Table 34.	Switching output I/O current consumption . . . . .	97
Table 35.	Peripheral current consumption . . . . .	99
Table 36.	Low-power mode wakeup timings . . . . .	102
Table 37.	High-speed external user clock characteristics. . . . .	103
Table 38.	Low-speed external user clock characteristics . . . . .	103
Table 39.	HSE 4-26 MHz oscillator characteristics . . . . .	105
Table 40.	LSE oscillator characteristics (f <sub>LSE</sub> = 32.768 kHz) . . . . .	106
Table 41.	HSI oscillator characteristics . . . . .	107
Table 42.	LSI oscillator characteristics . . . . .	108

Table 43.	Main PLL characteristics . . . . .	108
Table 44.	PLL12S (audio PLL) characteristics . . . . .	109
Table 45.	PLLISAI characteristics . . . . .	110
Table 46.	SSCG parameters constraint . . . . .	111
Table 47.	Flash memory characteristics . . . . .	112
Table 48.	Flash memory programming . . . . .	113
Table 49.	Flash memory programming with $V_{PP}$ . . . . .	113
Table 50.	Flash memory endurance and data retention . . . . .	114
Table 51.	EMS characteristics . . . . .	115
Table 52.	EMI characteristics . . . . .	116
Table 53.	ESD absolute maximum ratings . . . . .	116
Table 54.	Electrical sensitivities . . . . .	117
Table 55.	I/O current injection susceptibility . . . . .	117
Table 56.	I/O static characteristics . . . . .	118
Table 57.	Output voltage characteristics . . . . .	121
Table 58.	I/O AC characteristics . . . . .	121
Table 59.	NRST pin characteristics . . . . .	123
Table 60.	TIMx characteristics . . . . .	124
Table 61.	I <sup>2</sup> C characteristics . . . . .	125
Table 62.	FMPI <sup>2</sup> C characteristics . . . . .	127
Table 63.	SPI dynamic characteristics . . . . .	129
Table 64.	QSPI dynamic characteristics in SDR Mode . . . . .	132
Table 65.	QSPI dynamic characteristics in DDR Mode . . . . .	132
Table 66.	I <sup>2</sup> S dynamic characteristics . . . . .	133
Table 67.	SAI characteristics . . . . .	136
Table 68.	USB OTG full speed startup time . . . . .	137
Table 69.	USB OTG full speed DC electrical characteristics . . . . .	138
Table 70.	USB OTG full speed electrical characteristics . . . . .	139
Table 71.	USB HS DC electrical characteristics . . . . .	139
Table 72.	USB HS clock timing parameters . . . . .	139
Table 73.	Dynamic characteristics: USB ULPI . . . . .	140
Table 74.	ADC characteristics . . . . .	141
Table 75.	ADC static accuracy at $f_{ADC} = 18$ MHz . . . . .	142
Table 76.	ADC static accuracy at $f_{ADC} = 30$ MHz . . . . .	143
Table 77.	ADC static accuracy at $f_{ADC} = 36$ MHz . . . . .	143
Table 78.	ADC dynamic accuracy at $f_{ADC} = 18$ MHz - limited test conditions . . . . .	143
Table 79.	ADC dynamic accuracy at $f_{ADC} = 36$ MHz - limited test conditions . . . . .	143
Table 80.	Temperature sensor characteristics . . . . .	147
Table 81.	Temperature sensor calibration values . . . . .	147
Table 82.	$V_{BAT}$ monitoring characteristics . . . . .	148
Table 83.	internal reference voltage . . . . .	148
Table 84.	Internal reference voltage calibration values . . . . .	148
Table 85.	DAC characteristics . . . . .	148
Table 86.	Asynchronous non-multiplexed SRAM/PSRAM/NOR - read timings . . . . .	154
Table 87.	Asynchronous non-multiplexed SRAM/PSRAM/NOR read - NWAIT timings . . . . .	154
Table 88.	Asynchronous non-multiplexed SRAM/PSRAM/NOR write timings . . . . .	155
Table 89.	Asynchronous non-multiplexed SRAM/PSRAM/NOR write - NWAIT timings . . . . .	156
Table 90.	Asynchronous multiplexed PSRAM/NOR read timings . . . . .	157
Table 91.	Asynchronous multiplexed PSRAM/NOR read-NWAIT timings . . . . .	157

Table 92.	Asynchronous multiplexed PSRAM/NOR write timings . . . . .	159
Table 93.	Asynchronous multiplexed PSRAM/NOR write-NWAIT timings . . . . .	159
Table 94.	Synchronous multiplexed NOR/PSRAM read timings . . . . .	161
Table 95.	Synchronous multiplexed PSRAM write timings . . . . .	163
Table 96.	Synchronous non-multiplexed NOR/PSRAM read timings . . . . .	164
Table 97.	Synchronous non-multiplexed PSRAM write timings . . . . .	166
Table 98.	Switching characteristics for NAND Flash read cycles . . . . .	168
Table 99.	Switching characteristics for NAND Flash write cycles . . . . .	169
Table 100.	SDRAM read timings . . . . .	170
Table 101.	LPSDR SDRAM read timings . . . . .	170
Table 102.	SDRAM write timings . . . . .	171
Table 103.	LPSDR SDRAM write timings . . . . .	172
Table 104.	DCMI characteristics . . . . .	172
Table 105.	Dynamic characteristics: SD / MMC characteristics . . . . .	174
Table 106.	Dynamic characteristics: eMMC characteristics VDD = 1.7 V to 1.9 V . . . . .	175
Table 107.	RTC characteristics . . . . .	175
Table 108.	LQFP64 – 10 x 10 mm low-profile quad flat package mechanical data . . . . .	176
Table 109.	LQPF100, 14 x 14 mm 100-pin low-profile quad flat package mechanical data . . . . .	179
Table 110.	LQFP144, 20 x 20 mm, 144-pin low-profile quad flat package mechanical data . . . . .	183
Table 111.	UFBGA144 - 144-pin, 7 x 7 mm, 0.50 mm pitch, ultra fine pitch ball grid array package mechanical data . . . . .	186
Table 112.	UFBGA144 recommended PCB design rules (0.50 mm pitch BGA) . . . . .	187
Table 113.	UFBGA144 - 144-pin, 10 x 10 mm, 0.80 mm pitch, ultra fine pitch ball grid array package mechanical data . . . . .	189
Table 114.	UFBGA144 recommended PCB design rules (0.80 mm pitch BGA) . . . . .	190
Table 115.	WLCSP81- 81-pin, 3.693 x 3.815 mm, 0.4 mm pitch wafer level chip scale package mechanical data . . . . .	192
Table 116.	WLCSP81 recommended PCB design rules (0.4 mm pitch) . . . . .	193
Table 117.	Package thermal characteristics . . . . .	195
Table 118.	Ordering information scheme . . . . .	196
Table 119.	Document revision history . . . . .	200

# 1 Introduction

This document provides the description of the STM32F446xC/E products.

The STM32F446xC/E document should be read in conjunction with the STM32F4xx reference manual.

For information on the Cortex<sup>®</sup>-M4 core, please refer to the Cortex<sup>®</sup>-M4 programming manual (PM0214), available from the [www.st.com](http://www.st.com).

## 2 Description

The STM32F446xC/E devices are based on the high-performance ARM® Cortex®-M4 32-bit RISC core operating at a frequency of up to 180 MHz. The Cortex-M4 core features a Floating point unit (FPU) single precision which supports all ARM® single-precision data-processing instructions and data types. It also implements a full set of DSP instructions and a memory protection unit (MPU) which enhances application security.

The STM32F446xC/E devices incorporate high-speed embedded memories (Flash memory up to 512 Kbyte, up to 128 Kbyte of SRAM), up to 4 Kbytes of backup SRAM, and an extensive range of enhanced I/Os and peripherals connected to two APB buses, two AHB buses and a 32-bit multi-AHB bus matrix.

All devices offer three 12-bit ADCs, two DACs, a low-power RTC, twelve general-purpose 16-bit timers including two PWM timers for motor control, two general-purpose 32-bit timers.

They also feature standard and advanced communication interfaces.

- Up to four I<sup>2</sup>Cs;
- Four SPIs, three I<sup>2</sup>Ss full simplex. To achieve audio class accuracy, the I<sup>2</sup>S peripherals can be clocked via a dedicated internal audio PLL or via an external clock to allow synchronization;
- Four USARTs plus two UARTs;
- An USB OTG full-speed and an USB OTG high-speed with full-speed capability (with the ULPI), both with dedicated power rails allowing to use them throughout the entire power range;
- Two CANs;
- Two SAs serial audio interfaces. To achieve audio class accuracy, the SAs can be clocked via a dedicated internal audio PLL;
- An SDIO/MMC interface;
- Camera interface;
- HDMI-CEC;
- SPDIF Receiver (SPDIFRx);
- QuadSPI.

Advanced peripherals include an SDIO, a flexible memory control (FMC) interface, a camera interface for CMOS sensors. Refer to [Table 2: STM32F446xC/E features and peripheral counts](#) for the list of peripherals available on each part number.

The STM32F446xC/E devices operates in the –40 to +105 °C temperature range from a 1.7 to 3.6 V power supply.

The supply voltage can drop to 1.7 V with the use of an external power supply supervisor (refer to [Section 3.16.2: Internal reset OFF](#)). A comprehensive set of power-saving mode allows the design of low-power applications.

The STM32F446xC/E devices offer devices in 6 packages ranging from 64 pins to 144 pins. The set of included peripherals changes with the device chosen.

These features make the STM32F446xC/E microcontrollers suitable for a wide range of applications:

- Motor drive and application control
- Medical equipment
- Industrial applications: PLC, inverters, circuit breakers
- Printers, and scanners
- Alarm systems, video intercom, and HVAC
- Home audio appliances

**Table 2. STM32F446xC/E features and peripheral counts**

Peripherals		STM32F446MC	STM32F446ME	STM32F446RC	STM32F446RE	STM32F446VC	STM32F446VE	STM32F446ZC	STM32F446ZE
Flash memory in Kbytes		256	512	256	512	256	512	256	512
SRAM in Kbytes	System	128 (112+16)							
	Backup	4							
FMC memory controller		No				Yes <sup>(1)</sup>			
Timers	General-purpose	10							
	Advanced-control	2							
	Basic	2							
Communication interfaces	SPI / I <sup>2</sup> S	4/3 (simplex) <sup>(2)</sup>							
	I <sup>2</sup> C	4/1 FMP +							
	USART/UART	4/2							
	USB OTG FS	Yes (6-Endpoints)							
	USB OTG HS	Yes (8-Endpoints)							
	CAN	2							
	SAI	2							
	SDIO	Yes							
	SPDIF-Rx	1							
	HDMI-CEC	1							
Quad SPI <sup>(3)</sup>	1								
Camera interface		Yes							
GPIOs		63		50		81		114	
12-bit ADC Number of channels		3							
		14		16		16		24	
12-bit DAC Number of channels		Yes 2							
Maximum CPU frequency		180 MHz							
Operating voltage		1.8 to 3.6 V <sup>(4)</sup>							
Operating temperatures		Ambient temperatures: -40 to +85 °C / -40 to +105 °C							
		Junction temperature: -40 to + 125 °C							
Packages		WLCSP81		LQFP64		LQFP100		LQFP144 UFPGA144	

1. For the LQFP100 package, only FMC Bank1 or Bank2 are available. Bank1 can only support a multiplexed NOR/PSRAM memory using the NE1 Chip Select. Bank2 can only support a 16- or 8-bit NAND Flash memory using the NCE2 Chip Select. The interrupt line cannot be used since Port G is not available in this package.
2. The SPI1, SPI2 and SPI3 interfaces give the flexibility to work in an exclusive way in either the SPI mode or the I2S audio mode.
3. For the LQFP64 package, the Quad SPI is available with limited features.
4.  $V_{DD}/V_{DDA}$  minimum value of 1.7 V is obtained when the device operates in reduced temperature range, and with the use of an external power supply supervisor (refer to [Section 3.16.2: Internal reset OFF](#)).

## 2.1 Compatibility with STM32F4 family

The STM32F446xC/xV is software and feature compatible with the STM32F4 family.

The STM32F446xC/xV can be used as drop-in replacement of the other STM32F4 products but some slight changes have to be done on the PCB board.

Figure 1. Compatible board design for LQFP100 package

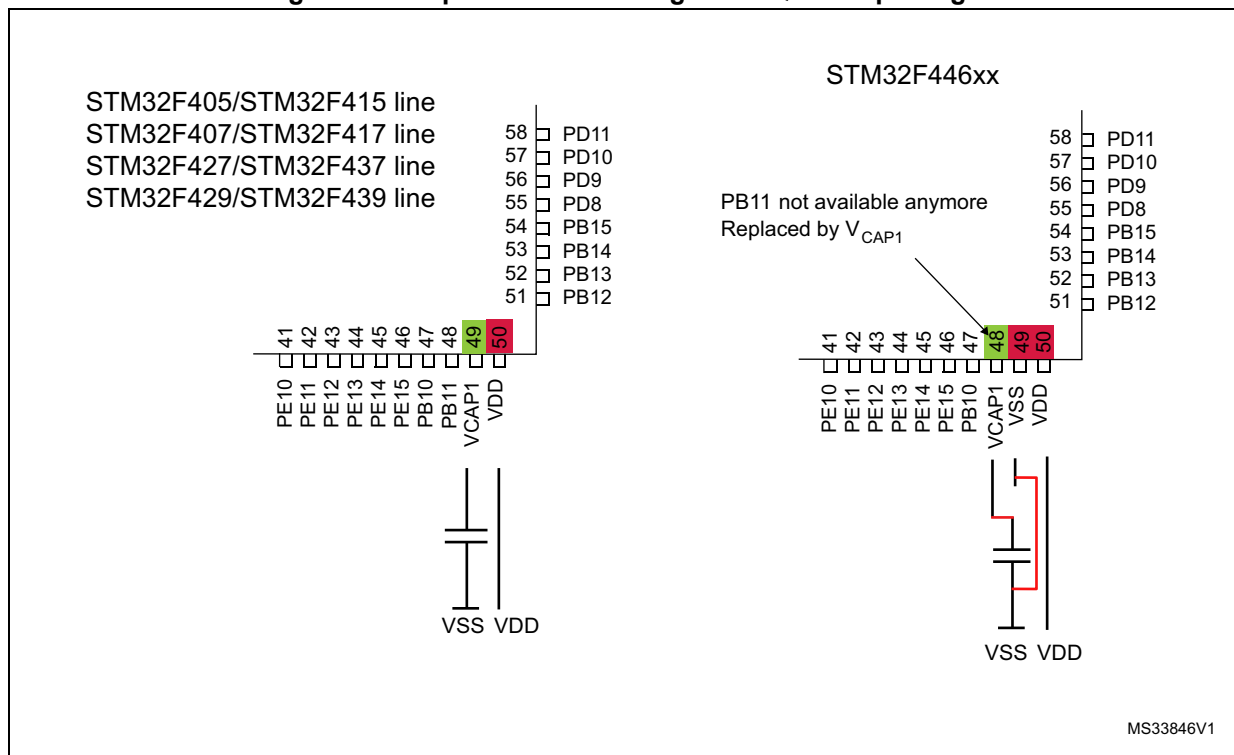


Figure 2. Compatible board for LQFP64 package

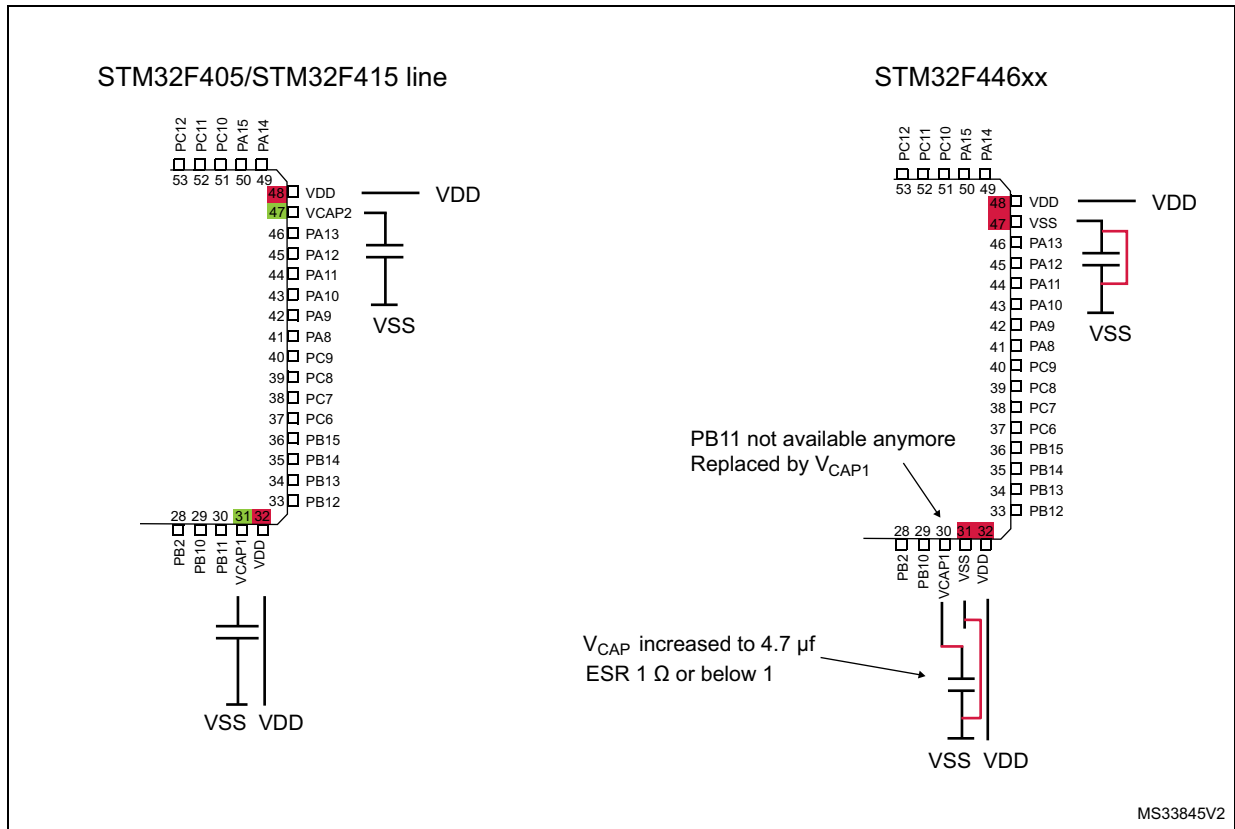
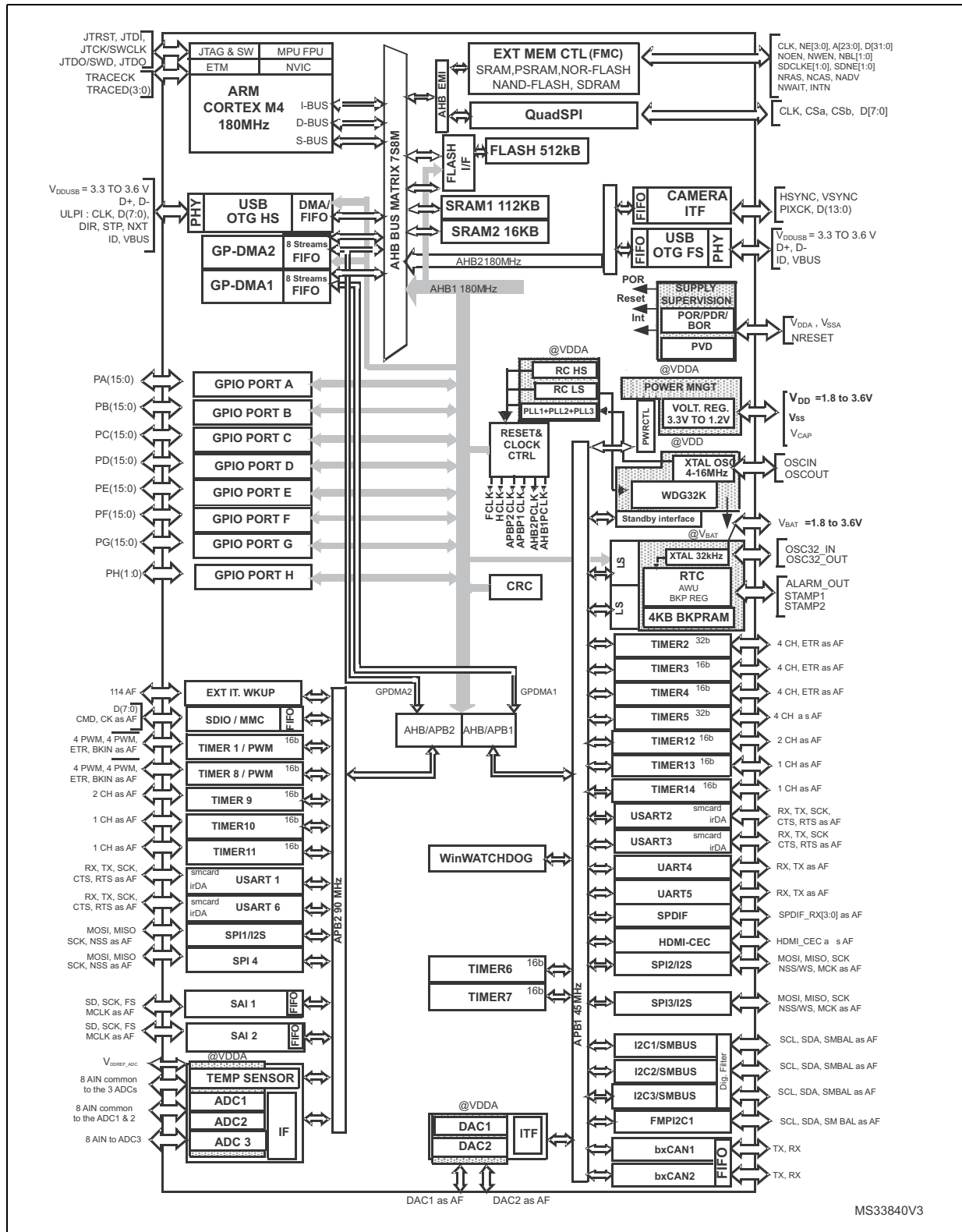


Figure 3 shows the STM32F446xx block diagram.



Figure 3. STM32F446xC/E block diagram



MS33840V3

## 3 Functional overview

### 3.1 ARM<sup>®</sup> Cortex<sup>®</sup>-M4 with FPU and embedded Flash and SRAM

The ARM<sup>®</sup> Cortex<sup>®</sup>-M4 with FPU processor is the latest generation of ARM processors for embedded systems. It was developed to provide a low-cost platform that meets the needs of MCU implementation, with a reduced pin count and low-power consumption, while delivering outstanding computational performance and an advanced response to interrupts.

The ARM<sup>®</sup> Cortex<sup>®</sup>-M4 with FPU core is a 32-bit RISC processor that features exceptional code-efficiency, delivering the high-performance expected from an ARM core in the memory size usually associated with 8- and 16-bit devices.

The processor supports a set of DSP instructions which allow efficient signal processing and complex algorithm execution.

Its single precision FPU (floating point unit) speeds up software development by using metalanguage development tools, while avoiding saturation.

The STM32F446xC/E family is compatible with all ARM tools and software.

*Figure 3* shows the general block diagram of the STM32F446xC/E family.

*Note:* Cortex-M4 with FPU core is binary compatible with the Cortex-M3 core.

### 3.2 Adaptive real-time memory accelerator (ART Accelerator™)

The ART Accelerator™ is a memory accelerator which is optimized for STM32 industry-standard ARM<sup>®</sup> Cortex<sup>®</sup>-M4 with FPU processors. It balances the inherent performance advantage of the ARM<sup>®</sup> Cortex<sup>®</sup>-M4 with FPU over Flash memory technologies, which normally requires the processor to wait for the Flash memory at higher frequencies.

To release the processor full 225 DMIPS performance at this frequency, the accelerator implements an instruction prefetch queue and branch cache, which increases program execution speed from the 128-bit Flash memory. Based on CoreMark benchmark, the performance achieved thanks to the ART Accelerator is equivalent to 0 wait state program execution from Flash memory at a CPU frequency up to 180 MHz.

### 3.3 Memory protection unit

The memory protection unit (MPU) is used to manage the CPU accesses to memory to prevent one task to accidentally corrupt the memory or resources used by any other active task. This memory area is organized into up to 8 protected areas that can in turn be divided up into 8 subareas. The protection area sizes are between 32 bytes and the whole 4 gigabytes of addressable memory.

The MPU is especially helpful for applications where some critical or certified code has to be protected against the misbehavior of other tasks. It is usually managed by an RTOS (real-time operating system). If a program accesses a memory location that is prohibited by the MPU, the RTOS can detect it and take action. In an RTOS environment, the kernel can dynamically update the MPU area setting, based on the process to be executed.

The MPU is optional and can be bypassed for applications that do not need it.

### 3.4 Embedded Flash memory

The devices embed a Flash memory of 512KB available for storing programs and data.

### 3.5 CRC (cyclic redundancy check) calculation unit

The CRC (cyclic redundancy check) calculation unit is used to get a CRC code from a 32-bit data word and a fixed generator polynomial.

Among other applications, CRC-based techniques are used to verify data transmission or storage integrity. In the scope of the EN/IEC 60335-1 standard, they offer a means of verifying the Flash memory integrity. The CRC calculation unit helps compute a software signature during runtime, to be compared with a reference signature generated at link-time and stored at a given memory location.

### 3.6 Embedded SRAM

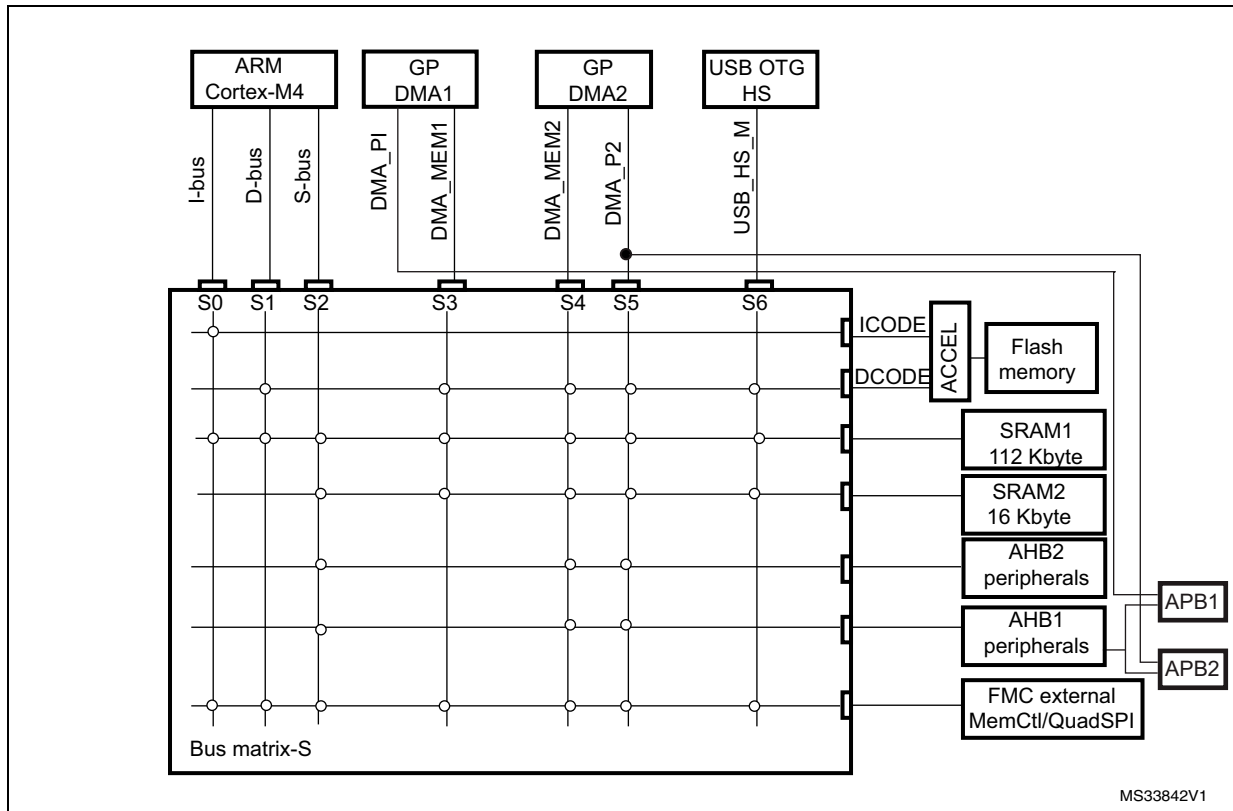
All devices embed:

- Up to 128Kbytes of system SRAM.  
RAM memory is accessed (read/write) at CPU clock speed with 0 wait states.
- 4 Kbytes of backup SRAM  
This area is accessible only from the CPU. Its content is protected against possible unwanted write accesses, and is retained in Standby or VBAT mode.

### 3.7 Multi-AHB bus matrix

The 32-bit multi-AHB bus matrix interconnects all the masters (CPU, DMAs, USB HS) and the slaves Flash memory, RAM, QuadSPI, FMC, AHB and APB peripherals and ensures a seamless and efficient operation even when several high-speed peripherals work simultaneously.

Figure 4. STM32F446xC/E and Multi-AHB matrix



### 3.8 DMA controller (DMA)

The devices feature two general-purpose dual-port DMAs (DMA1 and DMA2) with 8 streams each. They are able to manage memory-to-memory, peripheral-to-memory and memory-to-peripheral transfers. They feature dedicated FIFOs for APB/AHB peripherals, support burst transfer and are designed to provide the maximum peripheral bandwidth (AHB/APB).

The two DMA controllers support circular buffer management, so that no specific code is needed when the controller reaches the end of the buffer. The two DMA controllers also have a double buffering feature, which automates the use and switching of two memory buffers without requiring any special code.

Each stream is connected to dedicated hardware DMA requests, with support for software trigger on each stream. Configuration is made by software and transfer sizes between source and destination are independent.

The DMA can be used with the main peripherals:

- SPI and I<sup>2</sup>S
- I<sup>2</sup>C
- USART
- General-purpose, basic and advanced-control timers TIMx
- DAC
- SDIO
- Camera interface (DCMI)
- ADC
- SAI1/SAI2
- SPDIF Receiver (SPDIFRx)
- QuadSPI

### 3.9 Flexible memory controller (FMC)

All devices embed an FMC. It has seven Chip Select outputs supporting the following modes: SDRAM/LPSDR SDRAM, SRAM, PSRAM, NOR Flash and NAND Flash. With the possibility to remap FMC bank 1 (NOR/PSRAM 1 and 2) and FMC SDRAM bank 1/2 in the Cortex-M4 code area.

Functionality overview:

- 8-,16-bit data bus width
- Read FIFO for SDRAM controller
- Write FIFO
- Maximum FMC\_CLK/FMC\_SDCLK frequency for synchronous accesses is 90 MHz.

#### LCD parallel interface

The FMC can be configured to interface seamlessly with most graphic LCD controllers. It supports the Intel 8080 and Motorola 6800 modes, and is flexible enough to adapt to specific LCD interfaces. This LCD parallel interface capability makes it easy to build cost-effective graphic applications using LCD modules with embedded controllers or high performance solutions using external controllers with dedicated acceleration.

### 3.10 Quad SPI memory interface (QUADSPI)

All devices embed a Quad SPI memory interface, which is a specialized communication interface targeting Single, Dual or Quad SPI flash memories. It can work in direct mode through registers, external flash status register polling mode and memory mapped mode. Up to 256 Mbytes external flash are memory mapped, supporting 8, 16 and 32-bit access. Code execution is supported. The opcode and the frame format are fully programmable. Communication can be either in Single Data Rate or Dual Data Rate.

### 3.11 Nested vectored interrupt controller (NVIC)

The devices embed a nested vectored interrupt controller able to manage 16 priority levels, and handle up to 91 maskable interrupt channels plus the 16 interrupt lines of the Cortex<sup>®</sup>-M4 with FPU core.

- Closely coupled NVIC gives low-latency interrupt processing
- Interrupt entry vector table address passed directly to the core
- Allows early processing of interrupts
- Processing of late arriving, higher-priority interrupts
- Support tail chaining
- Processor state automatically saved
- Interrupt entry restored on interrupt exit with no instruction overhead

This hardware block provides flexible interrupt management features with minimum interrupt latency.

### 3.12 External interrupt/event controller (EXTI)

The external interrupt/event controller consists of 23 edge-detector lines used to generate interrupt/event requests. Each line can be independently configured to select the trigger event (rising edge, falling edge, both) and can be masked independently. A pending register maintains the status of the interrupt requests. The EXTI can detect an external line with a pulse width shorter than the Internal APB2 clock period. Up to 114 GPIOs can be connected to the 16 external interrupt lines.

### 3.13 Clocks and startup

On reset the 16 MHz internal RC oscillator is selected as the default CPU clock. The 16 MHz internal RC oscillator is factory-trimmed to offer 1% accuracy at 25 °C. The application can then select as system clock either the RC oscillator or an external 4-26 MHz clock source. This clock can be monitored for failure. If a failure is detected, the system automatically switches back to the internal RC oscillator and a software interrupt is generated (if enabled). This clock source is input to a PLL thus allowing to increase the frequency up to 180 MHz. Similarly, full interrupt management of the PLL clock entry is available when necessary (for example if an indirectly used external oscillator fails).

Several prescalers allow the configuration of the two AHB buses, the high-speed APB (APB2) and the low-speed APB (APB1) domains. The maximum frequency of the two AHB buses is 180 MHz while the maximum frequency of the high-speed APB domains is 90 MHz. The maximum allowed frequency of the low-speed APB domain is 45 MHz.

The devices embed a dedicated PLL (PLLI2S) and PLLSAI which allows to achieve audio class performance. In this case, the I<sup>2</sup>S master clock can generate all standard sampling frequencies from 8 kHz to 192 kHz.

### 3.14 Boot modes

At startup, boot pins are used to select one out of three boot options:

- Boot from user Flash
- Boot from system memory
- Boot from embedded SRAM

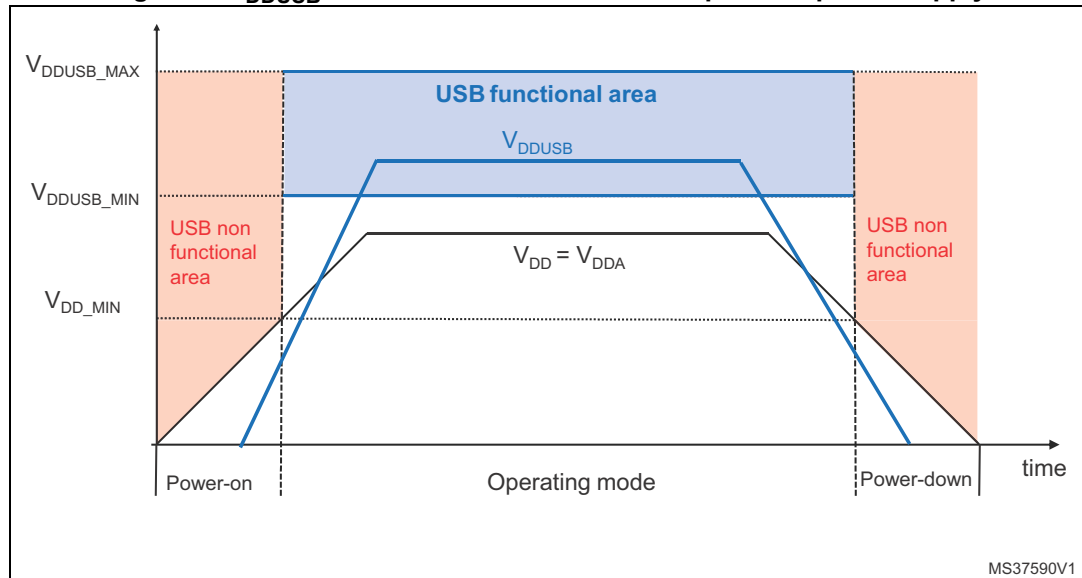
The boot loader is located in system memory. It is used to reprogram the Flash memory through a serial (UART, I<sup>2</sup>C, CAN, SPI and USB) communication interface. Refer to application note AN2606 for details.

### 3.15 Power supply schemes

- $V_{DD} = 1.7$  to  $3.6$  V: external power supply for I/Os and the internal regulator (when enabled), provided externally through  $V_{DD}$  pins.
- $V_{SSA}, V_{DDA} = 1.7$  to  $3.6$  V: external analog power supplies for ADC, DAC, Reset blocks, RCs and PLL.  $V_{DDA}$  and  $V_{SSA}$  must be connected to  $V_{DD}$  and  $V_{SS}$ , respectively.

*Note:*  $V_{DD}/V_{DDA}$  minimum value of 1.7 V is obtained with the use of an external power supply supervisor (refer to [Section 3.16.2: Internal reset OFF](#)). Refer to [Table 3: Voltage regulator configuration mode versus device operating mode](#) to identify the packages supporting this option.

- $V_{BAT} = 1.65$  to  $3.6$  V: power supply for RTC, external clock 32 kHz oscillator and backup registers (through power switch) when  $V_{DD}$  is not present.
- $V_{DDUSB}$  can be connected either to  $V_{DD}$  or an external independent power supply (3.0 to 3.6V) for USB transceivers.  
For example, when device is powered at 1.8V, an independent power supply 3.3V can be connected to  $V_{DDUSB}$ . When the  $V_{DDUSB}$  is connected to a separated power supply, it is independent from  $V_{DD}$  or  $V_{DDA}$  but it must be the last supply to be provided and the first to disappear. The following conditions  $V_{DDUSB}$  must be respected:
  - During power-on phase ( $V_{DD} < V_{DD\_MIN}$ ),  $V_{DDUSB}$  should be always lower than  $V_{DD}$
  - During power-down phase ( $V_{DD} < V_{DD\_MIN}$ ),  $V_{DDUSB}$  should be always lower than  $V_{DD}$
  - $V_{DDUSB}$  rising and falling time rate specifications must be respected.
  - In operating mode phase,  $V_{DDUSB}$  could be lower or higher than  $V_{DD}$ :
    - If USB (USB OTG\_HS/OTG\_FS) is used, the associated GPIOs powered by  $V_{DDUSB}$  are operating between  $V_{DDUSB\_MIN}$  and  $V_{DDUSB\_MAX}$ . The  $V_{DDUSB}$  supply both USB transceiver (USB OTG\_HS and USB OTG\_FS).
    - If only one USB transceiver is used in the application, the GPIOs associated to the other USB transceiver are still supplied by  $V_{DDUSB}$ .
    - If USB (USB OTG\_HS/OTG\_FS) is not used, the associated GPIOs powered by  $V_{DDUSB}$  are operating between  $V_{DD\_MIN}$  and  $V_{DD\_MAX}$ .

Figure 5.  $V_{DDUSB}$  connected to an external independent power supply

## 3.16 Power supply supervisor

### 3.16.1 Internal reset ON

On packages embedding the PDR\_ON pin, the power supply supervisor is enabled by holding PDR\_ON high. On the other package, the power supply supervisor is always enabled.

The device has an integrated power-on reset (POR)/ power-down reset (PDR) circuitry coupled with a Brownout reset (BOR) circuitry. At power-on, POR/PDR is always active and ensures proper operation starting from 1.8 V. After the 1.8 V POR threshold level is reached, the option byte loading process starts, either to confirm or modify default BOR thresholds, or to disable BOR permanently. Three BOR thresholds are available through option bytes. The device remains in reset mode when  $V_{DD}$  is below a specified threshold,  $V_{POR/PDR}$  or  $V_{BOR}$ , without the need for an external reset circuit.

The device also features an embedded programmable voltage detector (PVD) that monitors the  $V_{DD}/V_{DDA}$  power supply and compares it to the  $V_{PVD}$  threshold. An interrupt can be generated when  $V_{DD}/V_{DDA}$  drops below the  $V_{PVD}$  threshold and/or when  $V_{DD}/V_{DDA}$  is higher than the  $V_{PVD}$  threshold. The interrupt service routine can then generate a warning message and/or put the MCU into a safe state. The PVD is enabled by software.

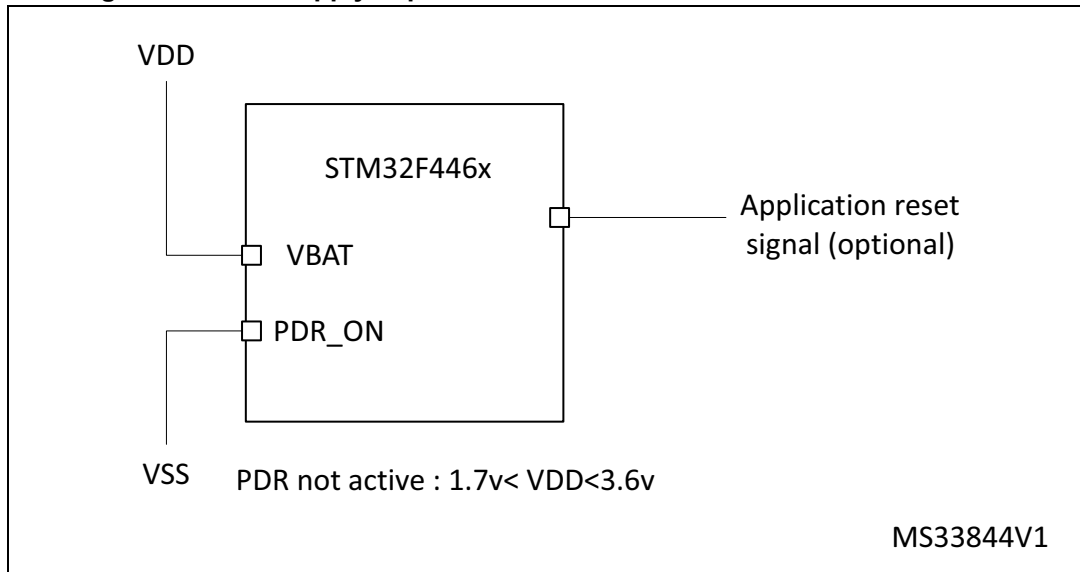
### 3.16.2 Internal reset OFF

This feature is available only on packages featuring the PDR\_ON pin. The internal power-on reset (POR) / power-down reset (PDR) circuitry is disabled through the PDR\_ON pin.

An external power supply supervisor should monitor  $V_{DD}$  and should maintain the device in reset mode as long as  $V_{DD}$  is below a specified threshold. PDR\_ON should be connected to VSS, to allow device to operate down to 1.7V. Refer to [Figure 6: Power supply supervisor interconnection with internal reset OFF](#).



Figure 6. Power supply supervisor interconnection with internal reset OFF



The  $V_{DD}$  specified threshold, below which the device must be maintained under reset, is 1.7 V.

A comprehensive set of power-saving mode allows to design low-power applications.

When the internal reset is OFF, the following integrated features are no more supported:

- The integrated power-on reset (POR) / power-down reset (PDR) circuitry is disabled
- The brownout reset (BOR) circuitry must be disabled
- The embedded programmable voltage detector (PVD) is disabled
- $V_{BAT}$  functionality is no more available and  $V_{BAT}$  pin should be connected to  $V_{DD}$ .

All packages, except for the LQFP100/LQFP64, allow to disable the internal reset through the PDR\_ON signal.

### 3.17 Voltage regulator

The regulator has four operating modes:

- Regulator ON
  - Main regulator mode (MR)
  - Low power regulator (LPR)
  - Power-down
- Regulator OFF

#### 3.17.1 Regulator ON

On packages embedding the BYPASS\_REG pin, the regulator is enabled by holding BYPASS\_REG low. On all other packages, the regulator is always enabled.

There are three power modes configured by software when the regulator is ON:

- MR mode used in Run/sleep modes or in Stop modes
  - In Run/Sleep mode
 

The MR mode is used either in the normal mode (default mode) or the over-drive mode (enabled by software). Different voltages scaling are provided to reach the best compromise between maximum frequency and dynamic power consumption. The over-drive mode allows operating at a higher frequency than the normal mode for a given voltage scaling.
  - In Stop modes
 

The MR can be configured in two ways during stop mode:  
 MR operates in normal mode (default mode of MR in stop mode)  
 MR operates in under-drive mode (reduced leakage mode).
- LPR is used in the Stop modes:
 

The LP regulator mode is configured by software when entering Stop mode. Like the MR mode, the LPR can be configured in two ways during stop mode:

  - LPR operates in normal mode (default mode when LPR is ON)
  - LPR operates in under-drive mode (reduced leakage mode).
- Power-down is used in Standby mode.
 

The Power-down mode is activated only when entering in Standby mode. The regulator output is in high impedance and the kernel circuitry is powered down, inducing zero consumption. The contents of the registers and SRAM are lost.

Refer to [Table 3](#) for a summary of voltage regulator modes versus device operating modes.

Two external ceramic capacitors should be connected on V<sub>CAP\_1</sub> and V<sub>CAP\_2</sub> pin.

All packages have the regulator ON feature.

**Table 3. Voltage regulator configuration mode versus device operating mode<sup>(1)</sup>**

Voltage regulator configuration	Run mode	Sleep mode	Stop mode	Standby mode
Normal mode	MR	MR	MR or LPR	-
Over-drive mode <sup>(2)</sup>	MR	MR	-	-
Under-drive mode	-	-	MR or LPR	-
Power-down mode	-	-	-	Yes

1. '-' means that the corresponding configuration is not available.

2. The over-drive mode is not available when V<sub>DD</sub> = 1.7 to 2.1 V.

### 3.17.2 Regulator OFF

This feature is available only on packages featuring the BYPASS\_REG pin. The regulator is disabled by holding BYPASS\_REG high. The regulator OFF mode allows to supply externally a V<sub>12</sub> voltage source through V<sub>CAP\_1</sub> and V<sub>CAP\_2</sub> pins.